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TITLE: TOUCH FASTENER ELEMENT LOOP RETENTION

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TOUCH FASTENER ELEMENT LOOP RETENTION

TECHNICAL FIELD

This invention relates to male touch fastener elements configured to releasably engage fibrous loops, and more particularly to such fastener elements with stems formed of molded resin.

BACKGROUND

Early male touch fastener products were generally woven materials, with hooks formed by cut filament loops. More recently, arrays of very small touch fastener elements have been formed by molding the fastener elements, or at least the stems of the elements, of resin forming an interconnecting sheet of material.

In most applications, male fastener elements are designed to releasably engage with a mating female fastener component carrying a field of loops or fibers. To engage the loops, the male fastener elements must penetrate the field of fibers at least until the tips of the engaging fastener element heads have sufficiently extended beyond some of the fibers, such that the fibers can be engaged within the crooks of the heads.

Subsequent to engagement, retention of an engaged fiber or loop depends, at least for loads within the ability of the loop to resist breakage, upon resistance of the hook to distention and/or breakage. Distention is the opening of the crook under load of an engaged loop. For high cycle life applications, breakage of either both loops and hooks is undesirable. Thus, the ability of the fastening to resist peel loads in such applications is generally limited by the ability of the hook to resist distention.

Unfortunately, for many applications increasing the rigidity of hooks designed for maximum loop penetration, to increase their peel resistance, is either undesirable or impractical. For example, many applications require a gentle 'feel' of the male fastener element array against the skin.

Further improvements in the overall design of male fastener elements, particularly those formed or molded of resin and arranged in large numbers upon a surface for engaging loops or fibers, are desired. Preferably, such improved fastener elements will be readily and efficiently manufacturable without great advances in manufacturing methods.

SUMMARY

According to one aspect of the invention, a touch fastener component has a sheet-form base and an array of fastener elements. Each fastener element includes a stem extending outwardly from and integrally with the sheet-form base, and a head extending from a distal end of the stem to a tip to overhang a forward edge of the stem, the head having a lower surface forming an arched crook for retaining loops. Specifically, the crook defines an under crook angle, measured about the crook in side view from a line normal to the forward edge of the stem at an elevation from the base corresponding to a lowermost extent of the tip, to a normal to the lower head surface, that is greater than about 180 degrees.

In some embodiments, each fastener element has multiple heads extending in different directions and forming separate crooks. For example, each fastener element may have two heads extending in essentially opposite directions.

In some cases, each fastener element defines an upper well between the two oppositely-directed heads, the well preferably extending down to a height, measured perpendicularly from the base, of at least about 70 percent of the overall height of one of the two oppositely-directed heads.

Each fastener element preferably has an overall length, between opposite extents of the oppositely-directed heads and measured parallel to the base, of at least 1.8 times the overall height of the fastener element.

A ratio of an overall height of the crook, measured perpendicular to the sheet-form base from a lowermost extent of the tip to an uppermost extent of the crook, to an entrance height measured perpendicular to the sheet-form base below a lowermost extent of the tip, is preferably greater than 0.6.

For some applications the head has an overall thickness, measured parallel to the base and perpendicular to a plane of the crook, that is greater than an entrance height measured perpendicular to the sheet-form base below a lowermost extent of the tip.

In some instances, the head and stem form a unitary molded structure, such as with the head having surfaces of resin cooled against a mold surface. The stem may also have opposing surfaces defined by severed resin, such as from being formed by a cut-and-stretch operation.

In some cases, the stem and head have side surfaces lying in parallel planes.

The forward edge of the stem preferably extends at an inclination angle of between about 20 and 30 degrees with respect to a normal to the base. For example, in one instance the inclination angle is about 23 degrees.

In preferred embodiments, each fastener element has an overall height of between about 10 and 50 millimeters, more preferably 20 to 30 millimeters.

Each fastener element head preferably has an overall height of between about 10 and 20 millimeters.

In some embodiments, each fastener element crook defines an overall crook height, measured perpendicular to the sheet-form base from a lowermost extent of the tip to an uppermost extent of the crook, of at least 6.0 millimeters.

The touch fastener component may have a backing material laminated to a side of the base opposite the fastener elements. In some cases, the backing material carries engageable loops.

The fastener elements are preferably arranged in a density of at least about 350 fastener elements per square inch of the base. The fastener elements together preferably cover at least 20 percent of an overall surface area of the base from which the fastener elements extend.

For some applications, the under crook angle is preferably at least about 190 degrees, more preferably at least 200 degrees.

Another aspect of the invention features a method of forming a touch fastener component having a sheet-form base and an array of fastener elements. Molten resin is introduced to a peripheral surface of a rotating mold roll defining an array of inwardly-extending cavities each including a stem region extending inwardly from the peripheral surface, and a head region extending laterally from a distal end of the stem region to a blind tip, the head region bounded by an outer surface forming a crook inward of a forward edge of the stem region. The crook defines an under crook angle, measured about the crook in side view from a line normal to the forward edge of the stem region at a mold roll radius to the tip, to a normal to the crook-forming outer surface, that is greater than about 180 degrees. Sufficient pressure is applied to force the resin into the cavities to mold an array of fastener elements, while forming a sheet of the resin on the peripheral surface of the mold roll. The resin is cooled in the cavities. Finally, the fastener elements are freed from the mold cavities

by stripping the sheet of resin from the surface of the mold roll, thereby pulling heads of the fastener elements formed in the head regions of the cavities through the stem regions of the cavities to remove the fastener elements from the cavities.

The improvements in hook design disclosed herein can provide a touch fastener product with particularly good peel resistance and other performance characteristics, and are especially applicable to hooks (whether J-hooks or multiple-crook hooks) that are molded contiguously with a sheet form base in accordance with known, cost-effective manufacturing methods. Increased stem taper, reflected in increased crook angle, beneficially increases rigidity of the stem against cross-machine bending and torsion. A large crook angle is particularly useful for retaining loops of large fiber diameter, high resiliency and in less dense loop field distributions, once they are engaged. A large crook angle can also enhance the potential for engagement and retention of multiple loops at one time within a single crook.

The illustrated embodiments are also found to be effective in retaining high-strength, low-loft loops for high cycle life fastening applications.

The details of one or more embodiments of the invention are set forth in the accompanying drawings and the description below. Other features, objects, and advantages of the invention will be apparent from the description and drawings, and from the claims.

DESCRIPTION OF DRAWINGS

Fig. 1 is a perspective view of male fastener component with palm tree-shaped hooks.

Fig. 2 is an enlarged photograph of an example of the fastener of Fig. 1.

Fig. 3 is an enlarged side view of one of the fastener elements.

Figs. 3A and 3B are top and end views, respectively, of the fastener element of Fig. 3.

Fig. 4 is a perspective view of an alternate palm tree hook shape.

Figs. 4A and 4B are top and end views, respectively, of the fastener element of Fig. 4.

Fig. 5 is an enlarged side view of a J-hook fastener element.

Fig. 6 and 6A illustrate alternate molding processes for forming the fastener components.

Fig. 7 is a side view of the J-hook fastener element of Fig. 5, illustrating loop confinement area.

Like reference symbols in the various drawings indicate like elements.

DETAILED DESCRIPTION

Referring to Figs. 1 and 2, a male touch fastener component 100 includes a field of fastener elements 102 arranged in rows R extending outwardly from and integrally with a sheet-form base 104. Spacing S between rows may be controlled by the manufacturing process and will be discussed further below. Fastener elements 102 are palm tree-shaped hooks and are engageable in two directions along a plane (i.e., an engagement plane) perpendicular to sheet-form base 104 the in direction of rows R. Each fastener element 102 includes two heads 106 extending from a single stem 108.

Male fastener component 100 is designed to, for example, strongly engage a low pile height, loop touch fastener component, particularly a loop component with loops formed of, for example, a high strength multifilament yarn or a high strength monofilament. High strength loops are desirable for fasteners for high strength applications requiring high cycle life, as the resist breakage at higher peel loads. Typically, high strength yarns and monofilaments are made by extrusion. Generally, the process includes a drawdown step to impart orientation on the yarn or monofilament so as to improve, for example, tenacity of the yarn or monofilament. High strength fibers may also be formed by other methods, for example, by solution spinning. Suitable high strength loop filament materials include, for example, polyamides, polyesters, polyurethanes, ultra-high molecular weight solution spun polyethylene (e.g., SPECTRA® polyethylene), aramids (e.g., KEVLAR®), acrylics and rigid rod polymers like poly(p-phenylene-2,6-benzobisoxazole).

Referring now to Figs. 3, 3A and 3B, fastener element 102 has a substantially constant thickness from base to tip, and includes a stem 108 extending outwardly from and molded integrally with sheet-form base 104. For purposes of the present disclosure, we refer to the stem 108 as beginning at the upper surface of base 104 and ending at an elevation where the inner crook surface is perpendicular to the base, an elevation 250 above which the inner crook surface begins to overhang the stem 108 or sheet-form base. Fastener element 102 also includes two heads 106 extending in essentially opposite directions in an engagement plane. Heads 106 extend from distal end 250 of the stem to corresponding, oppositely-directed tips 252. Thus, fastener element 102 is an example of what is known in

the art as a 'palm-tree' fastener element. The heads 106 have upper surfaces that alone or together with the stem define a well 254 between the heads. Each head 106 has a lower surface that rises up through an apex 258 and then falls again, forming an arched crook 256 for retaining loops of a mating female touch fastener component.

The overall height A of fastener element 102 is measured in side view perpendicular to sheet-form base 104 from the top of the sheet-form base. Under crook height C is the distance measured in side view, perpendicular to the sheet-form base, between the lowermost extent of the tip 260 and the apex 258 of the crook. Entrance height E is the distance measured in side view, perpendicular to the sheet-form base, from the top of the sheet-form base to the lowermost extent of tip 260. If part of the stem is directly below the lowermost extent of the tip 260, then the distance is measured from that portion of the stem directly below to the lowermost extent of the tip 260. Head height J of fastener element 102 is measured perpendicular to sheet-form base 104 from the lowermost extent of tip 260 to the highest elevation of the head 106 above the base. In general, J will be the difference between A and E. Well height G is measured in side view from the lower extent of stem 108 to the lower extent of well 256 defined in the upper surface of the fastener element between the heads.

Width L of the fastener element is measured in side view and is the maximum lateral extent of the fastener element heads 106 as measured parallel to the sheet-form base. Hook thickness K is the overall thickness of the fastener element, taken at elevation 250 corresponding to the upper end of stem 108. In most cases other than instances where the heads have been formed subsequent to stem molding, the heads will lie completely within this hook thickness K. In the example shown, hook thickness is the same at all elevations. The product of head width L and thickness K we call the footprint of the fastener element, and is related to the area of contact between the hook product and a mating loop product during initial engagement, although it will be understood to not be an exact measure of such contact area. The product of footprint and head height J (i.e., K x L x J) we refer to as displacement volume. For a more detailed explanation of the relevance of hook volume to fastener performance, see Provost, U.S. Patent Number 5,315,740, the contents of which are incorporated herein by reference.

The front and rear surfaces of the stem define, in side profile, inclination angles ϕ of about 23 degrees with respect to vertical, with the width of the stem tapering to narrower away from the base, both for strength and ease of molding.

Under crook angle θ_m is an angle defined in the crook by inner surfaces of the head and stem, between a pair of line segments perpendicular to facing surfaces of the fastener element, in side view. Line segment l_1 is perpendicular to the forward edge of stem 108 at the elevation of the distal tip 260 of the head. Line segment l_2 is perpendicular to the under crook surface of the head at a point of inflection 'X' of the under head surface. In cases where there is not a smooth curvature transition inside the tip, such as where the underside of the head forms a sharp corner adjacent the tip, line segment l_2 should be taken as perpendicular to the underside surface of the head just above such a corner or discontinuity. As shown, angle θ_m is measured from the upper side of line segment l_1, about the crook, to the upper side of line segment l_2. For this illustrated example, θ_m is 201 degrees.

The linear and radial dimensions of the example illustrated in Figs. 3, 3A and 3B are as follows:

Dimension	Inches	Millimeters
A	0.025	0.635
C	0.0064	0.163
E	0.0105	0.267
G	0.0122	0.310
J	0.0145	0.368
K	0.012	0.305
L	0.0497	1.262
R_1	0.0011	0.279
R_2	0.0090	0.229
R_3	0.0026	0.0660
R_4	0.0040	0.102
R_5	0.0107	0.272
R_6	0.0164	0.417

These values result in a footprint of 5.96×10^{-4} square inches ($0.00385\ cm^2$), and a displacement volume of about 8.65×10^{-6} cubic inches ($0.000142\ cm^3$). Given a hook density of 380 fastener elements per square inch, the overall fastener component has an overall hook footprint of 22.6 percent of the overall array area.

Further description of the embodiment of Fig. 3 can be found in an application entitled "MULTIPLE-CROOK MALE TOUCH FASTENER ELEMENTS," filed concurrently herewith and assigned U.S. Serial Number __________, the disclosure of which is hereby incorporated in full by reference.

Some examples have varying thickness, and non-planar sides. For example, the fastener element 102a of Figs. 4, 4A and 4B has a greatest thickness at its base, and tapers in thickness to the distal tips of the heads. However, as seen in side view, fastener element 102a has the same profile as shown in Fig. 3, and approximately the same dimensions listed above also apply to this example.

Not all palm-tree fastener elements have two identical crooks. For example, some palm-tree fastener elements are intentionally formed to have one head extending up higher than the other, such as to engage loops of differing heights. Also, some palm-tree hooks are molded to have two identical crooks, but later processing alters one crook more than the other, such as discussed below.

Not all examples are of the 'palm-tree' variety. For example, the fastener element 302 of Fig. 5 defines only a single crook, and is thus an example of a 'J-hook' fastener element. In this case, head width L is taken from the forwardmost edge of the hook head 306 to the rearmost extent of the hook stem 308. Otherwise, with the exception of well height G as inapplicable to J-hooks, the dimensions provided above with respect to Fig. 3 apply equally to the J-hook of Fig. 5. Both, for example, exhibit tapering stem cross-sections that enable demolding from molding cavities. Fastener elements 302 can be arranged in rows extending from a sheet-form base 304, with hooks of adjacent rows facing in opposite directions. Other arrangements of such hooks are also envisioned.

The fastener elements of Figs. 3-5 can be molded in the shapes shown. Referring to Fig. 6, thermoplastic resin 200 is extruded as a molten sheet from extruder 202 and introduced into nip 204 formed between a pressure roll 206 and a counter-rotating mold roll 208 defining fastener element-shaped cavities in its surface. Pressure in the nip causes

thermoplastic resin 200 to enter these blind-ended forming cavities to form the fastener elements, while excess resin remains about the periphery of the mold roll and is molded between the rolls to form sheet-form base 104. The thermoplastic resin is cooled as it proceeds along the periphery of the mold roll, solidifying the fastener elements, until it is stripped by stripper roll 212. The molded fastener elements distend during de-molding, but tend to recover substantially their as-molded shape. It is generally understood that fastener element crooks molded to face downstream tend to distend slightly more than those molded to face upstream, and can remain more distended in the final product. The direction of travel of the material illustrated in Fig. 6 is referred to as the "machine direction" (MD) of the material and defines the longitudinal direction of the resulting product, while the cross-machine direction (CD) is perpendicular to the machine direction within the plane of the sheet-form base. Further details regarding processing are described by Fischer, U.S. Patent Number 4,775,310 and Clune et al., U.S. Patent Number 6,202,260, the disclosures of which are hereby incorporated in full by reference.

In some embodiments, the mold roll 208 comprises a face-to-face assembly of thin, circular plates or rings (not shown) that are, for example, about 0.003 inch to about 0.250 inch (0.0762 mm-6.35 mm) thick, some having cutouts in their periphery defining mold cavities and others having solid circumferences, serving to close the open sides of the mold cavities and serve as spacers, defining the spacing between adjacent fastener element rows. A fully "built up" mold roll may have a width, for example, from about 0.75 inch to about 6 inches (1.91 cm-15.24 cm) or more and may contain, for example, from about 50 to 1000 or more individual rings. Further details regarding mold tooling are described by Fisher, U.S. Patent Number 4,775,310. Additional tooling embodiments will also be described below.

The cavities that made the fastener element shown in Fig. 3-3B have sharp edges and straight sidewalls and create fastener elements with substantially similar cross-sections through the thickness of the fastener element. Tooling with straight sidewalls and edges can be made by, for example, laser cutting, wire EDM or electroforming. Further details regarding laser cutting and wire EDM mold tooling is described by Fisher, U.S. Patent Number 4,775,310. The electroforming process is described by Clarner et al., U.S. Serial Number 10/455,240, the disclosure of which is hereby incorporated in full by reference.

By contrast, fastener elements formed in cavities that have been, for example, photochemically etched may have rounded surfaces in some or all regions, from base to tip, such as those illustrated in Figs. 4-4B. For example, surfaces at the top of the heads can be made to taper to a point to give a wedge effect. A wedge-shape may, for example, assist the entry of the crook into the face of a mating female fastener component. Further details regarding photochemical etching is described in Lacey et al., U.S. Patent Number 6,163,939, the entire disclosure of which is hereby incorporated in full by reference.

An alternate technique for molding fastener elements is shown in Fig. 6A. The process is similar to that described above with reference to Fig. 6, except only a mold roll 208 is used, i.e., no pressure roll 206 is necessary. Here, the extruder 202 is shaped to conform to the periphery of the mold roll 208 and the extruded resin 200 is introduced under pressure directly to a gap 214 formed between mold roll 208 and extruder 202. The molded fastener component is stripped from the mold cavities by a stripper roll 212 as described above. Further details regarding this process are described by Akeno, U.S. Patent Numbers 5,781,969 and 5,913,482, the disclosures of which are hereby incorporated in full by reference.

Referring next to Fig. 7, the space above line segments l_1 and l_2 forms a confinement space 400 into which loops 402 are drawn for engagement. The profile area of this confinement space is the area swept by the crook angle. As an engaged loop pulls upward at the apex 304 of the crook, the head 306 of the hook will distend, opening up the confinement area and shifting the orientation of line segment l_2 as the hook tip 308 moves upward. Eventually, at the limit of the ability of the hook to retain the loop, the hook distends enough that the loop is released. Because the crook angle is a function of both the extent to which the hook tip curves back toward the stem, and the taper angle of the forward edge of the stem, it is related both to the degree of hook tip displacement required for disengagement under a normal separation load, and to the strength of the stem to resist flexure that would otherwise facilitate such loop release. As both of these factors are related to the amount of normal force required for loop release, crook angle is found to be directly related to the ability of the hook to withstand higher peel loads. In closures that are 'hook limited,' in that the loop strength is stronger than the load required for hook distention, as is typically

desirable for high cycle life applications, increasing the hook peel resistance increases the performance of the overall closure.

As a measure of the 'encirclement' of the confinement area by the hook, crook angle is also related to the ability of the hook to resist unintended disengagement of loops at low loads. For very low crook angles, engaged loops can tend to exit the confinement area through the space between tip and base when the load on the loop is reduced or reversed.

A number of embodiments of the invention have been described. Nevertheless, it will be understood that various modifications may be made without departing from the spirit and scope of the invention. Accordingly, other embodiments are within the scope of the following claims.